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Coherent radiation from nonlinear plasma wakefields in the blowout regime

Coherent light sources, such as free electron lasers, provide bright beams for biology, chemistry, physics and advanced technological applications. As their brightness increases, these sources are also becoming progressively larger, with the longest being several km long (e.g. LCLS). Can we miniaturise these sources and bring them into university, hospital, and industrial-scale laboratories? Plasmas accelerator sources are an attractive solution to this question, but only if their brightness increases several orders of magnitude.

Here, we re-examine the fundamentals of superradiance and temporal coherence by exploring the radiation emitted by collective excitations, such as plasma waves. We show that the trajectory of a collective excitation defines the radiation as if it were a single, finite-sized super-charged particle. By applying this principle to nonlinear plasma waves in the nonlinear blowout regime, we identify new conditions leading to superradiance and temporal coherence in plasma-based accelerators [1]. We find that the plasma density can control the radiation frequency over a wide range, from THz to soft x-ray emission, and possibly beyond. We explore these concepts in theory and through particle-in-cell simulations complemented by the Radiation Diagnostic for Osiris (RaDiO) [2,3].

[1] B. Malaca et al, Nature Photonics 18 (1), 39-45 (2024)
[2] R.A. Fonseca et al, Plasma Physics and Controlled Fusion 55 (12), 124011 (2013)
[3] M. Pardal et al., Computer Physics Communications 285, 108634 (2023)

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